Advances in wind integration

Recent findings from international collaboration IEA WIND Task 25

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Introduction: On Task 25 work and Status of wind integration

Highlights from recent wind integration experience and results from integration studies

Recommendations for how to perform integration studies
IEA Wind Task 25 – What Does It Do?

Started in 2006, now 17 countries + WindEurope participate to provide an international forum for exchange of knowledge

State-of-the-art: review and analyze the results so far: latest report fall 2018

Formulate guidelines- Recommended Practices for Integration Studies: Update expected in July

Fact sheets and wind power production time series. Literature list.

https://community.ieawind.org/task25/
### IEA Wind Task 25

Design and operation of power systems with large amounts of wind power

18 countries + Wind Europe participate

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<td>Canada</td>
<td>Hydro Quebec (Alain Forcione, Nickie Menemenlis); NRCan (Thomas Levy)</td>
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<td>China</td>
<td>SGERI (Wang Yaohua, Liu Jun)</td>
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<td>Wind Europe</td>
<td>European Wind Energy Association (Ivan Pineda, Daniel Fraile)</td>
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Experience of wind integration is increasing

Higher and higher shares are being integrated in European countries, on average and as hourly maximum share:

- Denmark and Portugal > 100% of demand, Ireland > 60% of demand

Ireland monthly share 2011/12

total EU >11% in 2017
Experience: US

US states > 30% share of wind:
- Iowa, Kansas, Oklahoma, South Dakota

Highest hourly shares > 50%:
- SPP (Southwest Power Pool) and Ercot (Texas)

US: ~6% of electricity
First time in 2015 and several times since then, all central power plants shut down. The necessary system support is built into the grid:

- HVDC link: 700 MW Denmark-Norway
- synchronous compensators 4 in DK-W and 2 in DK-E
- and small scale power plants
Experience: Wind power giving frequency support

Colorado: wind used as AGC (secondary control) when curtailed

Texas: wind power plants actively used in frequency control: fast response actually contributes to reducing the overall need for frequency support services

Spain: more than 50% of wind power plants provide frequency support

- 6% of tertiary reserves from wind power in 2017

Source: Julia Matevosjana, ERCOT
Experience: curtailments

Curtailing wind power generation is one signal of lack of flexibility in the power system

• Due to delays of transmission: Italy and Texas – diminished after grid build out. Germany, still an issue

• Due to inflexibilities of coal power plants and tariffs: China

• Due to limits of non synchronous generation: Ireland (small system)
Operational practices: market design to enable wind integration

Enabling wind power plants to bid their flexibility to the markets

• With extra gains from balancing products
Value of flexibilities when large share of wind power

- Transmission and trade with neighbouring areas gives most value
- Power to heat offers flexibility in Northern Europe
- Demand response is cost effective when low costs
- Storage is still expensive
- All flexibilities together: less benefit than individual flexibilities separately

Value of flexibilities when large share of wind power

Case North Europe 40-50 % wind

Power system operational costs for one year, difference of with/without flexibility option
Towards higher shares of wind and solar energy

The time of base load power plants is over
• Less and less time operating (full load hours), resulting in costs/MWh getting high

The time of flexible power plants is here
• producing less than 5000 hours per year, much of that time at part load operation

NOTE: graph simplified presentation, flexibility options like demand side, storages and power to X will impact the net load and optimisation of generation mix
Recommended Practices for wind/PV integration studies

A complete study with links between phases
Most studies analyse part of the impacts – goals and approaches differ
What to study - Portfolio Development and System Management

Set-up of study

Main assumptions – Critical for results!

Future system, how wind/PV is added, what is remaining generation mix, operational practices

For larger shares and longer term studies:

• changes in the assumed remaining system become increasingly necessary, and beneficial: generation portfolio and network infrastructure, taking into account potential flexibility and technical capabilities of power plants. Additional scenarios for operating practices recommended
Operating reserve allocation with wind/PV

1. Synchronous wind/PV and load time series + forecast error distributions + generation outage distribution
2. Calculate for appropriate time scales, f.ex. automatically responding (secs-mins) and manually activated (mins-hour). Split data for categories with care not to double-count
3. Combine uncertainty keeping the same risk level before and after wind/PV
4. With increasing shares, use dynamic, not static reserves
Generation capacity adequacy

Needed for making consistent future scenarios (how much capacity will wind/PV replace), as integration study result: capacity value of wind or solar PV

Recommendations:

• How much increase in load will bring same reliability/LOLP in the system when adding wind or solar (ELCC method) recommended

• Input data – synchronous wind/PV/load data. Number of years critical for robust results, more than 10 years
Production cost simulation – flexibility assessment

Impact of wind/PV on other power plants’ operation. Simulated with Unit Commitment and Economic Dispatch (UCED) tools

Iteration loops /sensitivities often needed: results sensitive to base case selection (non-wind/PV case of comparison)

Input data: one year of hourly wind/PV data – synchronous with load (and hydro) and capturing smoothing impact and forecast accuracy
Recommendations for Unit Commitment and Economic Dispatch (UCED)

1. Impact of uncertainty on commitment decisions with possibilities to update forecasts (rolling planning)
2. Increased operating reserve targets
3. Flexibility limitations and constraints: min.generation levels, ramp rates, part load efficiency,..
4. Possible new flexibilities (power2heat, EVs, storages, demand response, dynamic line rating)
5. Possibilities and limitations of interconnections
   • model neighbouring system or mention assumption (over- or underestimating transfer possibilities)

6. Limitations from the transmission network require modeling of congestion and N-1 security
   • Net transfer capacity, or iterative methods can be used. Additional stability constraints for very high wind/PV shares.
Distribution network

*Distribution Grid Reinforcement Analysis:* grid optimization, before grid reinforcement, before grid expansion

*Grid Losses Analysis:* a detailed study of the grid losses for a certain number of reference grids, which represent other distribution grids, combined with statistical analysis or data-driven methods is recommended

Stronger coordination of transmission and distribution grid studies will be required with higher shares of wind/PV
Creating a number of credible power flow cases: more snapshots than peak and low load: critical situations regarding wind and solar power.

Steady-state power flow analyses with N-1 security criteria:

- Voltage profiles and network loading (congestion) assessment (probabilistic)
- Time series power flows for operation of discrete controllers and cross border flows
- Short circuit levels and protection
Wind/PV models important, validation also for other generators and load needed

Transient stability: include protection. Many mitigation options exist.

Voltage and frequency stability at higher shares of wind/PV

Small-signal stability, Sub-synchronous oscillations also when wind/PV displacing a lot of conventional generators, also transient events might become more severe (common-mode fault events)
• Iterations provide significant insights
• Comparisons to base case selected may impact results. Integration cost contradictory issue – so far no accurate methods found to extract system cost for a single technology
• Present the share of wind/PV for easier comparison with other studies

Analysing and Presenting the Results
Future work: integration studies are still evolving, towards 100% renewable studies

Metrics and tools for flexibility needs of the power system, and ways to achieve flexibility

Simulation tools that consider uncertainty of wind in different time scales, and combine network constraints with UCED constraints

Ways to set up simulation cases to efficiently extract impacts and system costs – from cost of integration to cost of inflexibility

Stability issues with very high penetration cases. Future grids with more DC transmission.

Implications of market design and/or regulatory processes for wind/PV integration.

Use the recommended practices check-list for benchmarking your study.